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Design and Implementation of Single Phase Solar PV System with Grid Interfacing

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Abstract - A grid tied photovoltaic (PV) power conversion topology is presented in this study with a novel scheme of re-synchronization to the grid. This scheme serves the purpose of supplying continuous power to the load along with feeding power to the grid. The control approach helps in mitigation of harmonics and improving the power quality while extracting the optimum power from the PV array. Depending on the availability of grid voltage, the proposed configuration is controlled using three approaches, defined as grid current control, Point of Common Coupling (PCC) voltage control and intentional islanding with re-synchronisation. A simple proportional integral controller manages the grid current, load voltage, battery current and DC Direct Current (DC) link voltage within these modes. Moreover, a control scheme for quick and smooth transitions among the modes is described. The robustness of the system under erratic behaviour of solar insolation, load power and disturbances in grid supply makes it a suitable choice for a residential application. The control, design and simulation results are presented to demonstrate the satisfactory operation of the proposed system.

Keywords – Single Phase, Solar PV, Grid, DC, PCC, PV, PV inverter.

I. INTRODUCTION

Renewable energy systems such as photovoltaic power generation, wind power generation and fuel cells are receiving a huge attention globally. Eco friendly power generation is the best feature of renewable energy systems. Renewable energy systems emit no pollution into the atmosphere when they generate electricity. However, most power plants such as thermal power generation and nuclear power generation plants have produced most of the power supply. But, Thermal and nuclear plant establish a danger impacts in the world.. On the other hand, renewable energy systems are very clean on a large-scale from the perspective of return of investment. In this paper, we propose a management system to maximize the efficiency of a photovoltaic power system in application's aspect. The combination of element technologies of renewable energy with commercial electricity result in high efficiency and positive results as described above. However, while research on the element technologies have been studied well, studies on energy management with renewable energy are not relatively developed. In case of on-grid photovoltaic systems connected to commercial electricity grids directly through Inverters like in figure 1, power consumption can be decreased in buildings or homes, but there could also be energy loss when power consumption is very low or electricity price are cheap, and vice versa. We are interfacing solar energy with grid. There are many types of renewable energy such as solar, wind, tidal etc., In our project we proposes solar energy since it is convenience for us.

II. GRID CONNECTED ROOFTOP PHOTOVOLTAIC SYSTEM

Figure 1 shows the schematic diagram of a grid connected photovoltaic system. It includes two PV module, two DC– DC converters, inverter, controllers and the grid. The DC– DC converters along with an MPPT controller are used to extract the maximum power from each PV module. DC to AC converter is used to interface the PV system to the grid.

Phase locked loop (PLL) controller is used for the synchronization of PV inverter with the grid. During grid connected mode, inverter operates in a current controlled mode with the help of a current controller. While, in grid isolated mode, a voltage controller is used to maintain the required terminal.

III. PV MODELING AND PARAMETER ESTIMATION

In order to analyze the grid connected PV system, it is essential to model the PV module connected to the system by using data available from the manufacturer's datasheet. However, some of the parameters required for the modeling of PV module are not given in the datasheet. All these parameters are estimated from datasheet values and then used in modeling.

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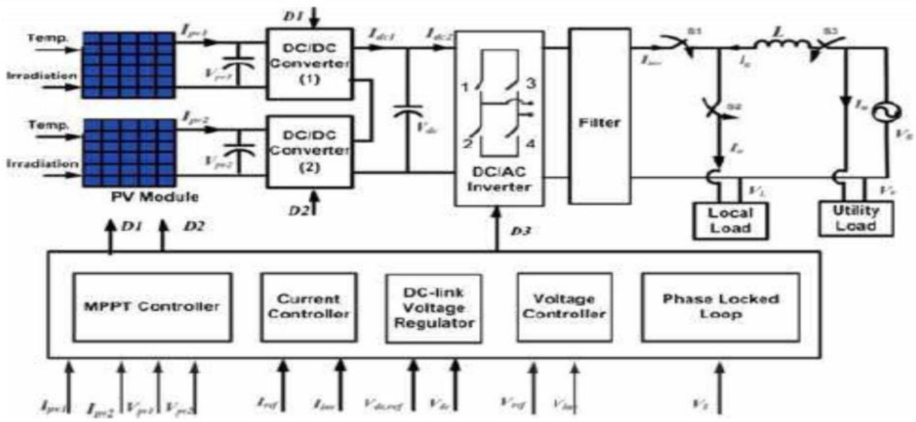

Figure 1. Schematic diagram of a $1-\phi$ grid connected PV system [31].

The equivalent circuit of a practical PV cell is shown in figure 2. The characteristic equation of a PV cell is expressed as [4],

$$I = I_{PV} - I_0 \left[\exp\left(\frac{V + I R_S}{N_s V_t} \right) - 1 \right] - \frac{V + I R_S}{R_{Sh}}. \quad (1)$$

The available parameters of the PV module and the parameters to be estimated are tabulated in table 1. The procedure for the parameter estimation is given below: Since the exponential term in Eq. (1) is much larger than 1, it can be re-written as

$$I = I_{PV} - I_0 \left[\exp\left(\frac{V + I R_S}{N_s V_t} \right) \right] - \frac{V + I R_S}{R_{Sh}}. \quad (2)$$

$$I_{SC} = I_{PV} - I_0 \left[\exp\left(\frac{I_{SC} R_S}{N_s V_t} \right) \right] - \frac{0 + I_{SC} R_S}{R_{Sh}} \quad (3)$$

$$I_{MPP} = I_{PV} - I_0 \left[\exp\left(\frac{V_{MPP} + I_{MPP} R_S}{N_s V_t} \right) \right] - \frac{V_{MPP} + I_{MPP} R_S}{R_{Sh}} \quad (4)$$

$$I_{PV} = I_0 \left[\exp\left(\frac{V_{OC}}{N_s V_t} \right) \right] + \frac{V_{OC}}{R_{Sh}}. \quad (5)$$

At MPP, the derivative of power with respect to voltage is zero [32].

$$\left. \frac{dP}{dV} \right|_{MPP} = 0. \quad (6)$$

Similarly, at short circuit condition [32],

$$\left. \frac{dI}{dV} \right|_{I=I_{SC}} = -\frac{1}{R_{Sh}}. \quad (7)$$

From Eqs. (5) and (3), I_0 can be expressed as

$$I_0 = \left(I_{SC} - \frac{V_{OC} - I_{SC} R_S}{R_{Sh}} \right) \exp\left(\frac{-V_{OC}}{N_s V_t} \right). \quad (8)$$

Substituting Eq. (8) in Eq. (5)

$$I_{PV} = I_{SC} + \frac{I_{SC} R_S}{R_{Sh}} \quad (9)$$

From Eq. (4) and Eq. (9),

$$I_{MPP} = \left[I_{SC} - \frac{V_{MPP} + I_{MPP} R_S - I_{SC} R_S}{R_{Sh}} \right] - \left[\left(I_{SC} - \frac{V_{OC} - I_{SC} R_S}{R_{Sh}} \right) e^{\left(\frac{V_{MPP} + I_{MPP} R_S - V_{OC}}{N_s V_t} \right)} \right]. \quad (10)$$

IV. CONTROL STRATEGY

Following controllers are used for the development of a single-phase grid connected PV system:

(1) Maximum power point tracking controller
(2) Grid synchronization controller
(3) PV inverter controller

The detailed description on each controller is given one by one in the following subsections:

4.1 *Maximum power point tracking control*

A DC–DC converter (step up/ step down) serves the purpose of extracting maximum power from the PV module. By

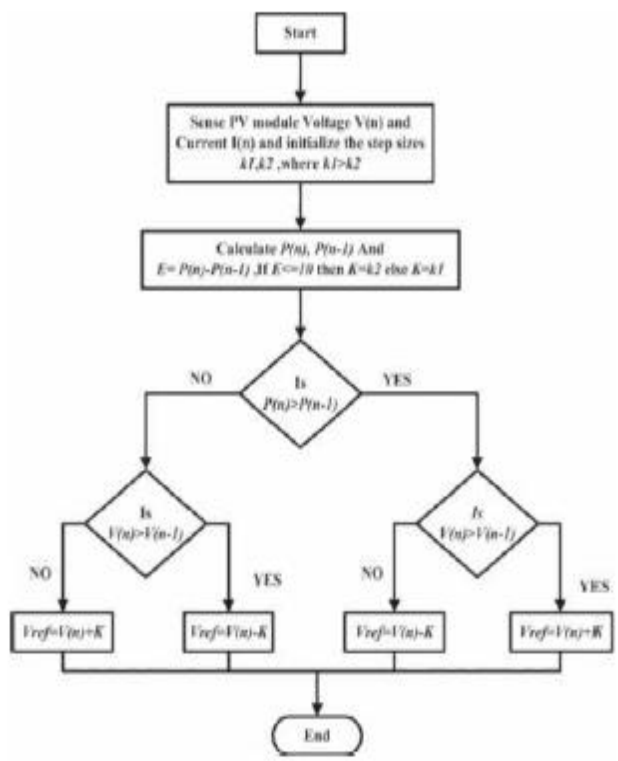

Figure 3. Flow chart for the MPPT control

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Figure 3. Flow chart for the MPPT control of PV module. changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source [6]. The perturb and observe (P&O) method is used here. It is an iterative method for obtaining MPP. It measures the PV array characteristics, and then perturbs the operating point of PV module to obtain the change in direction. The maximum point is reached when the rate of change of power with respect to voltage is zero. However, the major drawback of the conventional P&O is that, the process is repeated periodically until the MPP is reached. The system then oscillates about the MPP. The oscillation can be minimized by reducing the perturbation step size. However, a smaller perturbation size slows down the MPPT. An improved P&O algorithm is used here as a solution to this conflicting problem, which is shown in figure 3. Here, instead of the same perturbation size throughout the process, two step sizes (*k1* and *k2*, k1 > k2) are used. The operating voltage of the PV module is perturbed and the resulting change in power is measured. If *dP/dV* is positive, the perturbation of the operating voltage should be in the same direction as the increment. However, if it is negative, the system operating point is moving away from MPPT and the operating voltage should be perturbed in the opposite direction. Initially, when the error, i.e. E = P(n)−P(n−1) is large the algorithm selects the step size as K = k1 to have a fast tracking of MPP. However, at the instant whenE <= 10W i.e. less than 8% of the maximum power, a step size of k2 is chosen to have a minimum oscillation at the MPP. The exact value of k1 is chosen based on the tracking time of MPP and it can be calculated as follows

Let, T = Maximum tracking time of MPPT controller and Ts = Sampling time of the controller. Number of samples (or iteration) required for the MPPT controller to reach the MPP, Ns = T/Ts. In worst possible condition, the operating point has to cover from 0 V to VMPP V (under STCs)

within this Ns iteration. Therefore k1 can be calculated as, k1 =VMPP /Ns. However, to minimize the power ripple at MPP, the step size k2 is chosen as 1/10 times of k1

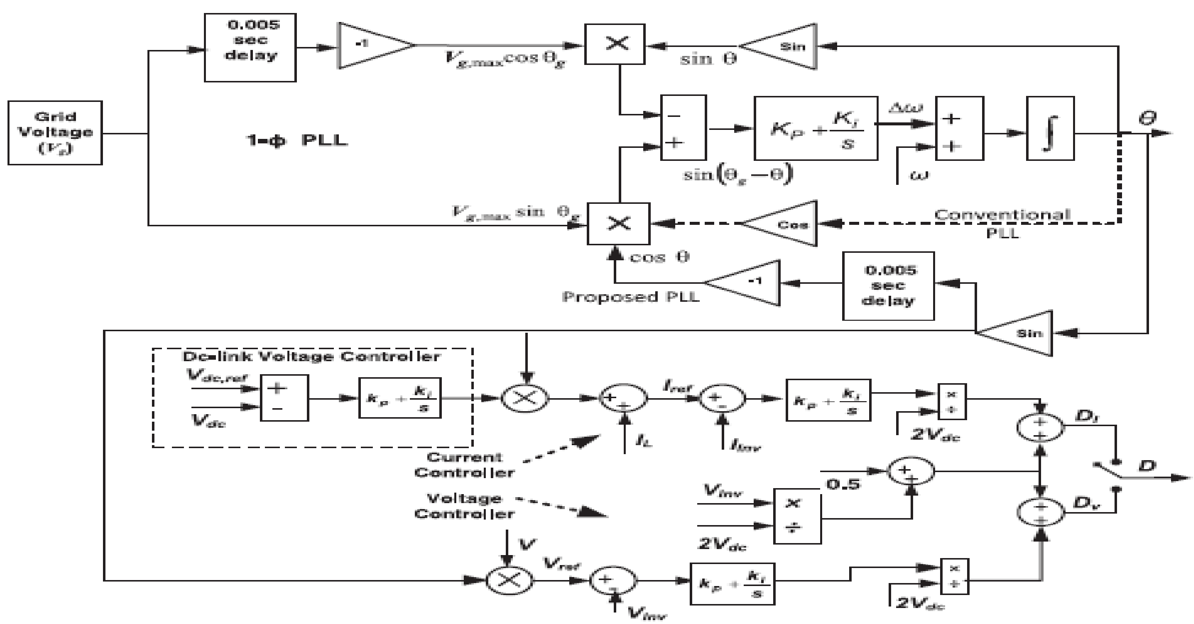

Figure 4. Complete control circuit for the proposed system.

4.2 *Grid synchronization controller*

Synchronization between the PV inverter and the grid means that both will have the same phase angle, frequency and amplitude. In order to accomplish this, a 1−φ phase locked loop (PLL) is used. It is a feedback control system which automatically adjusts the phase of a locally generated signal to match the phase of an input signal and hence provide a unity power factor operation. In a grid connected PV system the objective of the PLL is to synchronize the inverter output current with the grid voltage. The schematic diagram of the 1−φ PLL is shown in figure 4. Here the input to the PLL structure is the grid voltage and output is its phase angle. This phase angle is used to generate the sine wave which acts as a reference signal to the control system. The time required for the synchronization is dependent on the PI block parameters, which are computed below.

4.3 *PV inverter controller*

Since the PV system is operated in both grid connected and grid isolated mode, the controller requirement of which are different and hence discussed separately in the following subsections.

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4.3a *Grid connected mode*: During grid connected mode, the PV inverter operates as a current controlled source to generate an output current based on reference current The regulation of DC-link voltage carries the information regarding the exchange of active power between PV module and grid. Thus the output of DC-link controller results

V. CONCLUSION

This paper has presented a complete control strategy for a single-phase PV inverter operating in both grid connected and grid isolated mode. For the synchronization of PV inverter with the grid a single phase DTDPLL controller is presented. The performance of proposed DTDPLL controller is validated under varying frequency conditions. The grid connected PV system is tested under two different modes of operations, which are PV inverter control during grid connected operation and grid isolation operation. During grid connected operation, PV inverter operates in a current controlled mode. Under this mode of operation, the PV inverter feeds the surplus power to the grid during light load condition, whereas during overload conditions both the PV inverter and grid share the load requirement. During isolated grid operation, the PV inverter operates in voltage controlled mode to maintain a constant voltage.

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